Space Weather Technical Forecast

Issued on Saturday, 25 February 2023 at 00:49 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Large CME undergoing assessment. Otherwise R1-R2/Minor-Moderate radio blackouts likely throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 rose to Moderate in the UTC day of Friday 24 February, from a previous background of occasional mid-ranking C-class flares. The most significant events were an M1.1 at 24/1715UTC from AR3235 near the meridian in the northern solar hemisphere, but later and most notably an M3.7 at 24/2030UTC from a large, long-period filament eruption in the northwest quadrant. This filament had up to this point bisected one of the more significant regions on the disc, AR3229, in an arrangement that has since proven to be unstable. Tied to this later M3.7, a 10cm radio burst, Type IV radio burst and Type II radio burst were all observed, with the Type II's associated speed estimated at a not-insignificant 1204km/s. There has been a Coronal Mass Ejection (CME) subsequently observed on Lasco C2 imagery, with the shock visible heading at least partly northwest in early imagery, but with full assessment of the CME pending.

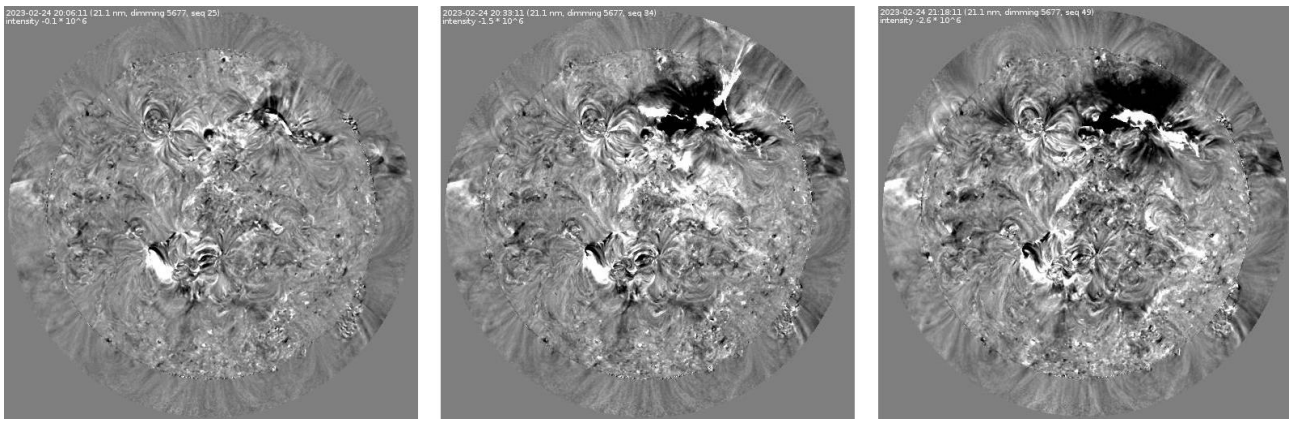

Figure 0: Time-integrated AIA211 difference imagery of the M3.7 24/2030UTC filament eruption CME from the vicinity of AR3229 in the northwest quadrant. Assessment is pending. Image processing courtesy of SIDC ROB.

The above was the most notable CME-generating event on the disc in the period, however there were several earlier candidates. These included a disappearing filament from the northern central disc near AR3235 at 24/0400UTC (visible in Learmonth H-alpha); a filament eruption from the southeastern quadrant as seen on Learmonth H-alpha at 24/0600UTC, between sunspot regions AR3230 and 3236; and a dimming from a C6.8 at 24/0709UTC from AR3235 in the northern central disc at 24/0700UTC. The northeast limb also saw a large and impulsive flare, CME and EIT wave at 24/1245UTC, with a non-Earth directed partial halo CME then clearly visible on subsequent coronagraph imagery. The final event of note was a south-central hemisphere dimming from near AR3230 at 24/1500UTC.

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At the time of writing the M3.7 flare CME was awaiting imagery for assessment, however none of the other front-sided events had obvious ejecta associated with them. The only other CME visible on coronagraphs was a fast and narrow far western hemisphere event visible in the UTC afternoon to no effect at Earth.

There were six sunspot regions on the visible disc in the period, with an unusually large proportion of these appearing to contain candidates for Mt Wilson delta spots. The main changes in the period were significant proliferation, spreading and areal growth of AR3236 in the southeast quadrant; slight spreading, intermediate spot development and areal fading in the trailing portion of the largest group, AR3234 in the northeast; and proliferation of leading spots at the expense of fading trailers in AR3229 in the northwest. All remaining regions showed less noteworthy trends. Mt Wilson deltas were observed in AR3234; 3235; 3236 and perhaps also more speculatively in AR3230.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR and ACE at L1, were possibly indicative of a chaotic alternating switching behaviour between CH77/+ and CH78/-, with the phi angle changeable but perhaps more often orientated away from the Sun (positive). The solar wind speed showed a gradual decline from Elevated levels and speeds near 600km/s in the period as the presumed connection to CH77/+ weakened, finishing at Slightly Elevated levels near 450km/s. The solar wind density fell from mid-teens ppcc as measured by DSCOVR to Background levels in the period. The IMF fell from +10nT to background nearer 5nT in the 24 hours, as the north-south component varied between +8 and -5nT. The character changed from an erratic tendency before midday UTC, with a discontinuity then observed ahead of a smoother and mainly co-aligned field with Earth's into the UTC afternoon.

The net result of the above solar wind measures was provisionally Quiet to Unsettled geomagnetic activity, falling from an early high of Kp '3-' in the 00-03UTC interval.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16 showed a rapid response to the northwest quadrant M3.7 at 24/2030UTC, with 10MeV rising to a peak of 3.5pfu at 24/2400UTC - short of the 10pfu required for S1.

High energy electron flux (greater than 2MeV) at GOES16 reached Moderate levels of around 450pfu for a period during the UTC afternoon before waning to Normal Background as part of its diurnal oscillation. The associated 24-hour electron fluence has been below the Active (1e8 integrated pfu) threshold on a near-level trend, reaching 1.61e7 integrated pfu at 25/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is Likely to be Moderate, with an ongoing Slight Chance of High activity, with the risk well-spread across most of the six current regions on the disc, and therefore more reliably maintained throughout. None of the current regions leave in the period, and there are signs of further arrivals over the eastern limb, meaning the risk of flares may increase into early next week, pending analysis.

Solar Wind / Geomagnetic Activity: There is one significant CME awaiting imagery for analysis - that associated with the M3.7 at 24/2030UTC. Keeping abreast of the forecast is advised. Of probably much less import is a possible glancing blow from a CME that left the northwest quadrant on 21 February, passing 1AU as a possible glancing blow from the shock on day one, Saturday 25 February.

Earth is currently transiting a sector of space influenced by the tail end of a positive polarity coronal hole (CH77). There are two further coronal holes, CH78 and CH79, which are expected to influence solar winds over the next four days. Overall, it seems likely that wind speeds will be Elevated or Slightly Elevated for much of this period, perhaps increasing to Strong by day three

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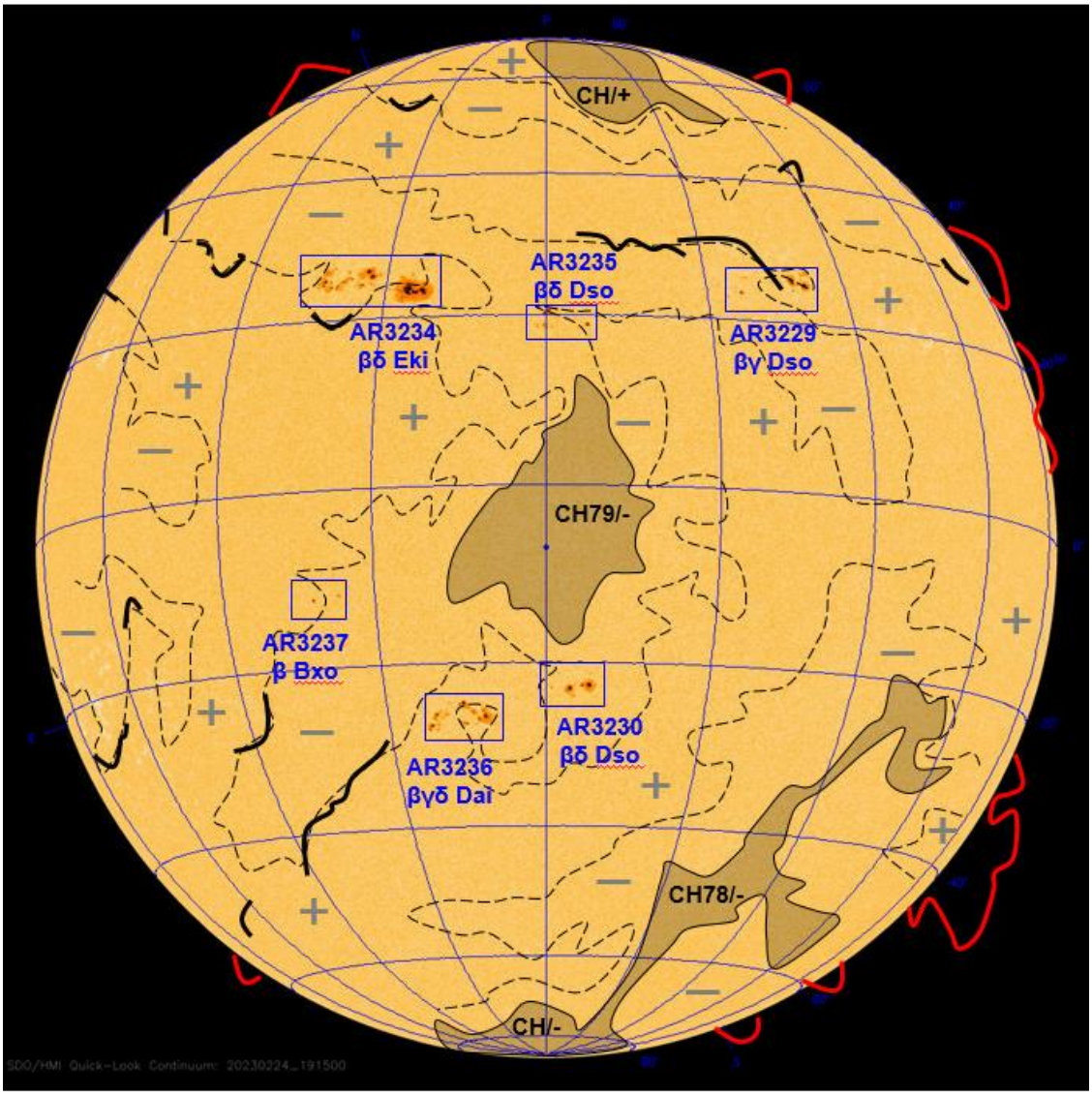
(Monday 27 February).

Overall, there is a risk of Minor Geomagnetic Storm on all days, starting as a Slight Chance, but tentatively peaking with a Chance from CH79 to end the current UTC weekend and start the new working week. Note that there may also be some influence from the as yet unassessed 24/2030UTC M3.7 CME.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is most likely to remain at background levels, but with an ongoing Slight Chance of reaching the S1 level.

High energy (greater than 2 MeV) electron flux is likely to reach Moderate, perhaps High levels with diurnal maxima. The associated 24-hour fluence is likely to remain below the Active threshold (1e8 integrated pfu) but with a possible erratic rising trend, although confidence is currently low.

Figure 1. Solar Analysis Valid 24/1915UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The shock from the northwest quadrant 21 February CME should pass 1AU on day one, Saturday 25 February. While the MOSWOC Enlil deterministic solution has this as a miss, a minority of ensemble members persist in showing a glancing blow, and this manifests in the forecast as a Slight Chance of G1. This is the only CME in the forecast at present, however note the one main unassessed candidate in the 24/2030UTC M3.7 event.

In terms of the ambient wind, STEREO A MAG and PLASTIC measurements show upcoming windspeeds in the next 24 hours as being in the Normal Background range (300-350km/s), although the density and IMF can be seen to rise - perhaps indicating a forerunning CIR ahead of CH78/-.

Earth is otherwise currently experiencing a declining fast wind with Slightly Elevated wind speeds. Variations in the observed phi angle may perhaps be explained by alternating connection between CH77/+ and perhaps CH78/-, although this is only a tentative hypothesis, and is not well-replicated at STEREO A. CH78 itself is a non-persistent feature - the bulk of which is well south on the disc, which has made judging the timing of the arrival of the HSS difficult. The leading edge of a further coronal hole, CH79/-, is just west of centre-disc and straddles the solar equator. This was present on the previous rotation but is larger this time around, perhaps with the leading edge a little further ahead. This arrived early on the equivalent of day three, (Monday 27 February) last time around, and could be a little earlier on this rotation with the leading edge being a little ahead.

Overall, it seems likely that wind speeds will be Elevated or Slightly Elevated for much of this period, perhaps increasing to Strong from the new working week (UTC). Both upcoming coronal holes have negative polarity, and therefore are more favoured for a geomagnetic response now we are approaching the March equinox.

Geomagnetic activity is expected to carry a risk of Minor Geomagnetic Storm G1 for the first three days at least, perhaps longer should the unassessed CME feature later in the forecast period. The peak risk is tied with CH79/-, which is currently mooted for later this UTC weekend and into the start of the new working week.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	30	30	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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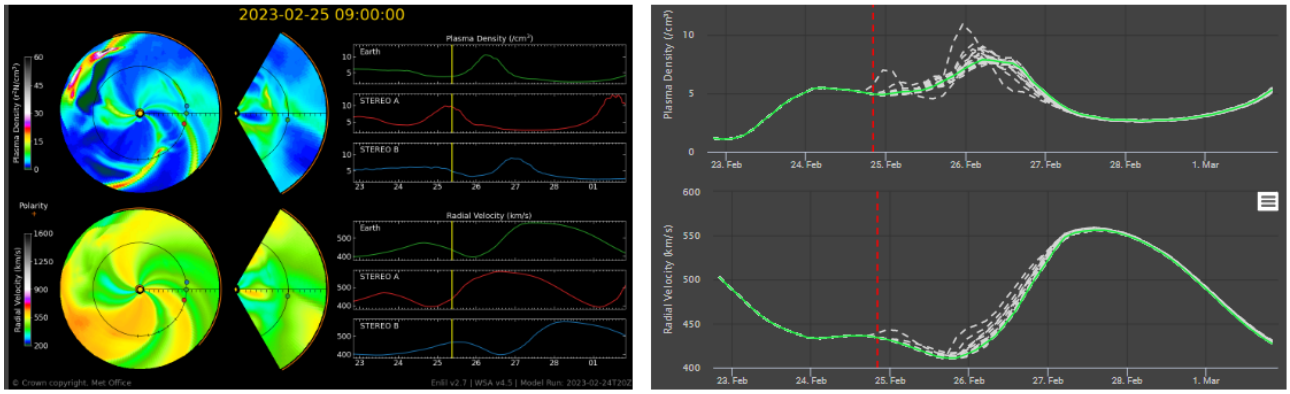
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Note that the 24/2030UTC M3.7 filament eruption from the northwest is as yet unassessed pending imagery.

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
21/1511	Partial(?)	Probable filament eruption	NW	378km/s	Probable miss	Visible shock heading largely north and west of Earth, some MOSWOC Enlil ensemble members display glancing blow on Saturday 25 February.

Figure 2: 24/2000UTC MOSWOC Enlil and ensemble, showing some members with glancing Earth incidence through the current UTC day. While this is not the most likely forecast, it is the rationale for the 5% Slight Chance of G1 through day one.



Radio Blackouts - X-Ray Flares:

There are six sunspot regions on the visible disc. Penticton 10.7cm flux appears to be starting an uptick, having previously been in decline since 09 February. This is manifesting in six relatively complex sunspot regions, with Mt Wilson Delta spots visible in at least three and perhaps four of the current cohort (AR3234; 3235; 3236 and perhaps also 3230). This means that activity can be presumed to be reasonably reliably maintained as there are so many potential sources on the disc in the four days.

The largest and nominally most complex region remains AR3234 in the northeast, which is borderline compact (Zurich class) and nearing becoming a F-group at 14 degrees span. Also of note is the remnant of AR3229, which had been in decline but has shown some reversal of this trend in the past 24 hours, and has played its part in destabilising the overlying filament that erupted from the northwest quadrant at 24/2030UTC - perhaps the most noteworthy event of the 24 hours.

Regarding the balance of groups expected in the forecast, none of the current front-side regions should leave the disc in the period, while the Carrington locations for up to six former regions are

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due in the four days over the eastern limb. While these have yet to be assessed, the expected outlook is therefore for greater activity in the coming week, assuming the front side remains unchanged.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: AIA094 time sequence of M3.7 flare from AR3229 and its overlying filament between 24/1955 and 24/2024UTC. The ejecta is clearly visible heading largely northwest, even in this near X-ray wavelength.

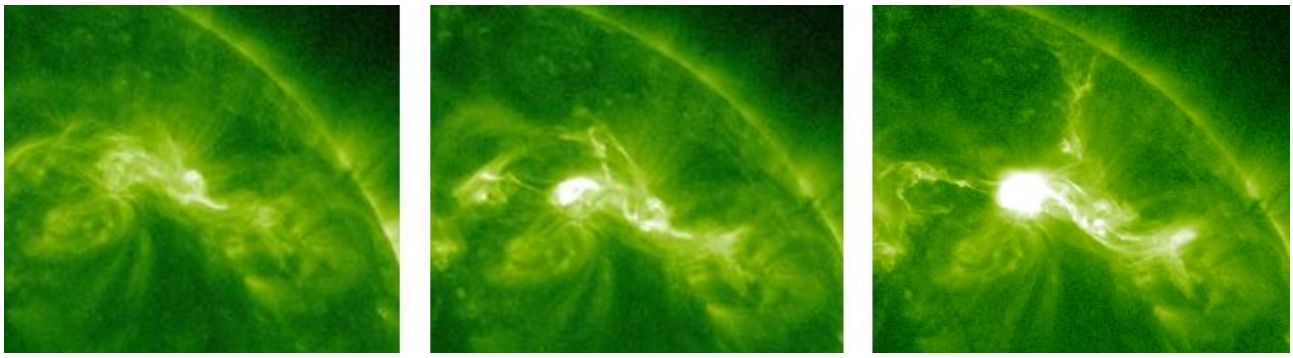
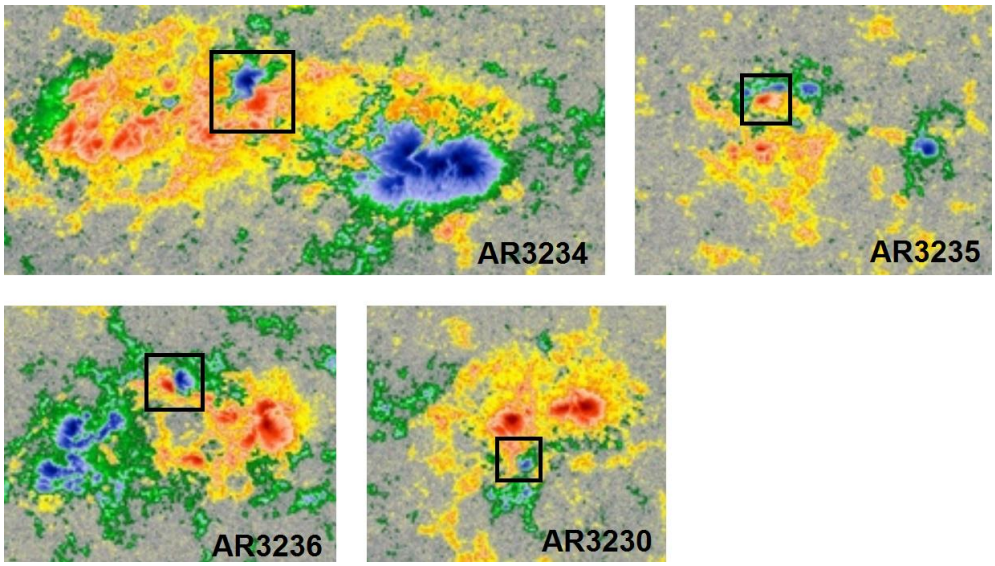


Figure 4: HMIBC imagery of four of the six sunspot regions on the disc as at 24/2400UTC, showing up to four Mt Wilson delta spots.



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Solar Radiation Storms - (High Energy Protons):

High energy (greater than 10MeV) proton flux, as observed by GOES16, is currently at Background levels, but displayed a rapid response to the 24/2030UTC M3.7 flare to 3.5pfu at the time of writing, likely because of its westward location on the disc. This event is likely to fall short of S1, but has slightly augmented the probabilities for day one, Saturday 24 February.

There remains a Slight Chance of an S1 or higher event, should any larger flares occur, with this risk reasonably well-partitioned between the six current sunspot groups on the disc.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	15	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Top: GOES16 high energy proton spectral response to the 24/2030UTC M3.7 flare; Bottom: GOES16 X-ray flux for the past 24 hours.

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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed at GOES16 is currently peaking at Moderate levels due to the influence of CH77. Further HSS influence is likely through much of this period, perhaps with a more significant HSS from CH79 arriving on day three (Sunday 26 February). This period is therefore likely to see a battle between the additive fast wind streams and (apparently) subtractive higher geomagnetic activity, with the risk probably highest into the new UTC week. In addition, faster wind speeds later in the period may compress the radiation belt inside GEO, with GOES16 perhaps not measuring the most charged part of the belt. As a consequence, confidence is low in this forecast.

The associated 24-hour fluence is likely to show an erratic rising trend. There is a possibility of exceeding the Active (1e8 integrated pfu) threshold through this period, peaking at the end of the four days in the throes of any arising Strong fast wind. MOSWOC REFM is suggesting a rise to near Active in its 72-hour scope, which is considered reasonable, although with significant uncertainty in the timing and intensity of any further rise given geometry changes of the faster coronal hole (CH79) and the non-persistent nature of the earlier CH78. Note that any impact from the unassessed 24/2030 M3.7 CME will further reduce confidence.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	10	20	40	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	10

Figure 6: Top: GOES16 greater than 2MeV high energy electron flux over the past 24 hours; bottom: observed 24-hour integrated fluence and 72-hour REFM forecast. Confidence is moderate given changes in the expected coronal holes and also the possible presence of an unassessed CME.

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